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# The Comparative Efficiencies of the Krupp Patent Grit-Mill and the Griffin Mill as applied to the Pulverization of Bituminous Coal for the Manufacture of Portland Cement

A Thesis submitted for the degree of Mechanical Engineer

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In the manufacture of portland cement by the Rotary Kiln Process, two methods of pulverizing the soft coal (which is used as fuel) are in general use.

The first method is by the employment of roller mills of which the Griffin is the most familiar type.

The second method is by the employment of the tube or pebble mills of which the Krupp, Smidth, and Clark are well known types.

Other methods of pulverizing the coal are in use but not so generally as the two methods mentioned above.

Tests were made on the Krupp Grit Mill and the Griffin Mill to ascertain which one of the two was the more economical to operate.

It may not be out of place to describe

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briefly the general method of pulverizing coal and the method of utilizing it in the rotary kiln as used in the manufacture of Portland Cement.

Before the coal is conveyed to the pulverizing mills, it is first necessary that it be thoroughly rid of any moisture which it may contain. To accomplish this it is first passed to the dryer.

The dryer consists essentially of a hollow cylinder made of sheet iron and supported upon trunnions, and given a pitch in the direction of its axis from one half to about three fourths of an inch to the foot.

The cylinder is encased in brick work the firebox being without the cylinder and built in the brick

work. By simply revolving the cylinder about its axis, the coal passes through the cylinder in a zig zag path until it finds its outlet at the rear end.

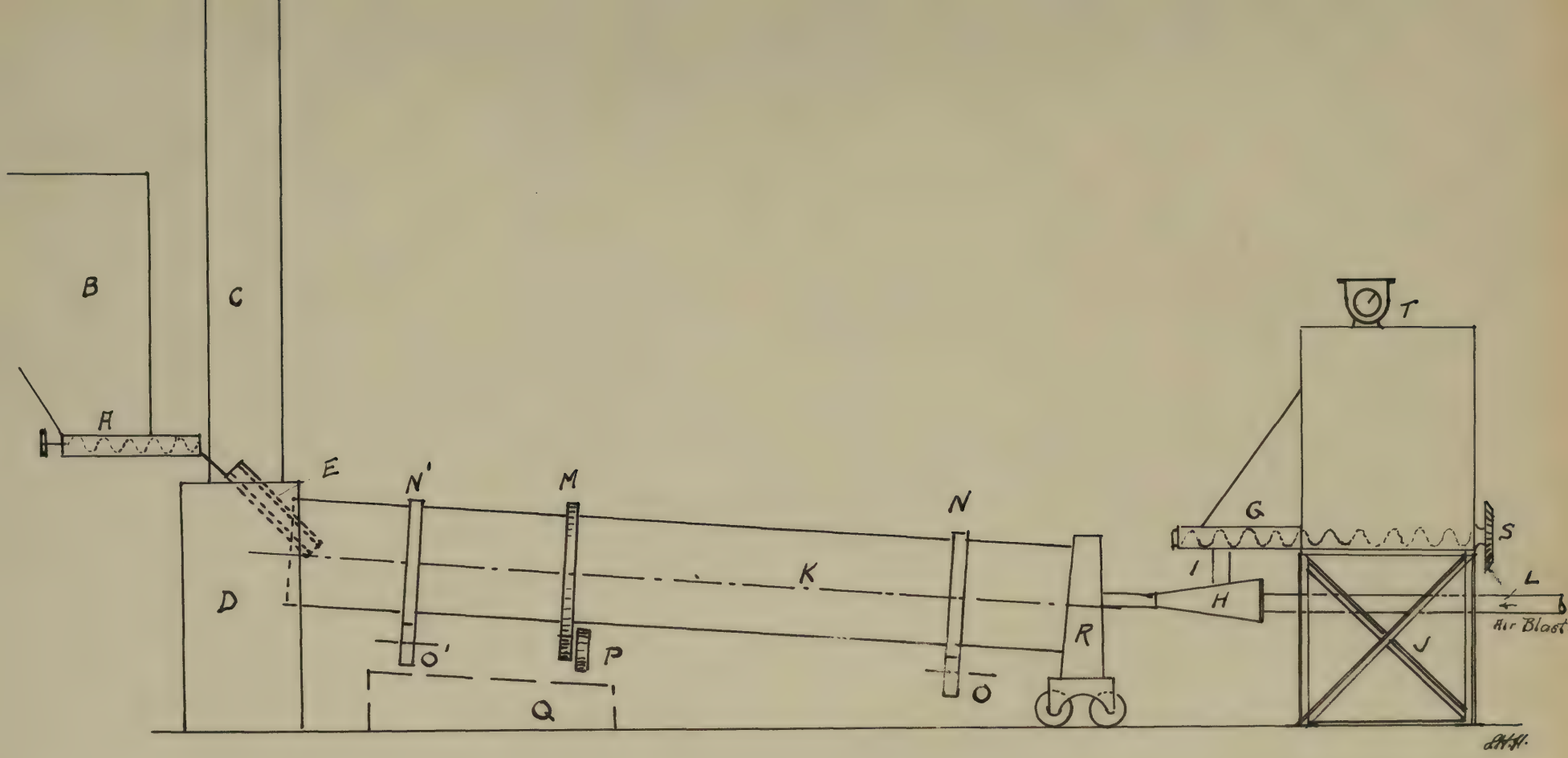
The hot gases from the furnace do not come directly in contact with the coal in most dryers, but first pass around the outside of the cylinder, then through the cylinder and then to the stack.

In some dryers the hot gases are not passed through the revolving cylinder, but are led around the outside by means of a system of baffle plates and then finally to the stack.

After leaving the dryer and having been rid of any moisture it may have contained, it is next conveyed

to the pulverizing mills to be prepared for burning in the kilns. The coal is pulverized to such a degree of fineness that only twelve percent will remain as residue on the standard sieve of one hundred meshes to the linear inch.

Plate I shows the general method of applying pulverized coal to a rotary kiln, B is the storage bin for the raw cement mixture, which is to be conveyed to the kiln by means of the screw conveyor F. The screw conveyor is driven by means of a system of chain gearing and is so arranged that the speed of the screw can be changed at will by the operator. Leaving the screw conveyor the material is introduced into the kiln through




Rotary Cement Kiln.

Plate I

the water jacketed tube E.
The kiln is pitched slightly to the horizontal from one half to three fourths of an inch to the foot, and revolves at a slow rate of speed, taking from one to three minutes to complete one revolution. The material then passes through the kiln in a zig-zag path and coming in contact with the intense heat of the coal flames is calcined into cement clinker.
The pulverized coal is contained in the storage bin, directly in front of the kiln and is fed to the injection apparatus or burner as it is commonly called by means of a screw conveyor whose speed can be adjusted at will by the operator.
The burner works almost on the same

principle as an injector or a steam draft inducer. The blast of air blown into the burner draws the coal into the apparatus where it is thoroughly mixed with air and injected into and ignited in the furnace arch.

Two systems of coal injecting are in use the first is known as the high pressure system in which the air supplied is at a pressure of forty pounds per square inch. Air compressors being used in this system.

The second system is known as the low pressure system the air being furnished by fan blowers at a pressure of 14 to 16 ounces per square inch. The apparatus in each case is somewhat different

but the object in each case is the same to thoroughly mix the coal dust with the air so as to form an explosive gas.
The finer the degree of pulverization the more nearly will this object be accomplished provided the air supply is sufficient.
It has been found to be practically good enough to carry the pulverization so far as to leave ten to twelve per cent as residue on a standard sieve of one hundred meshes to the linear inch.

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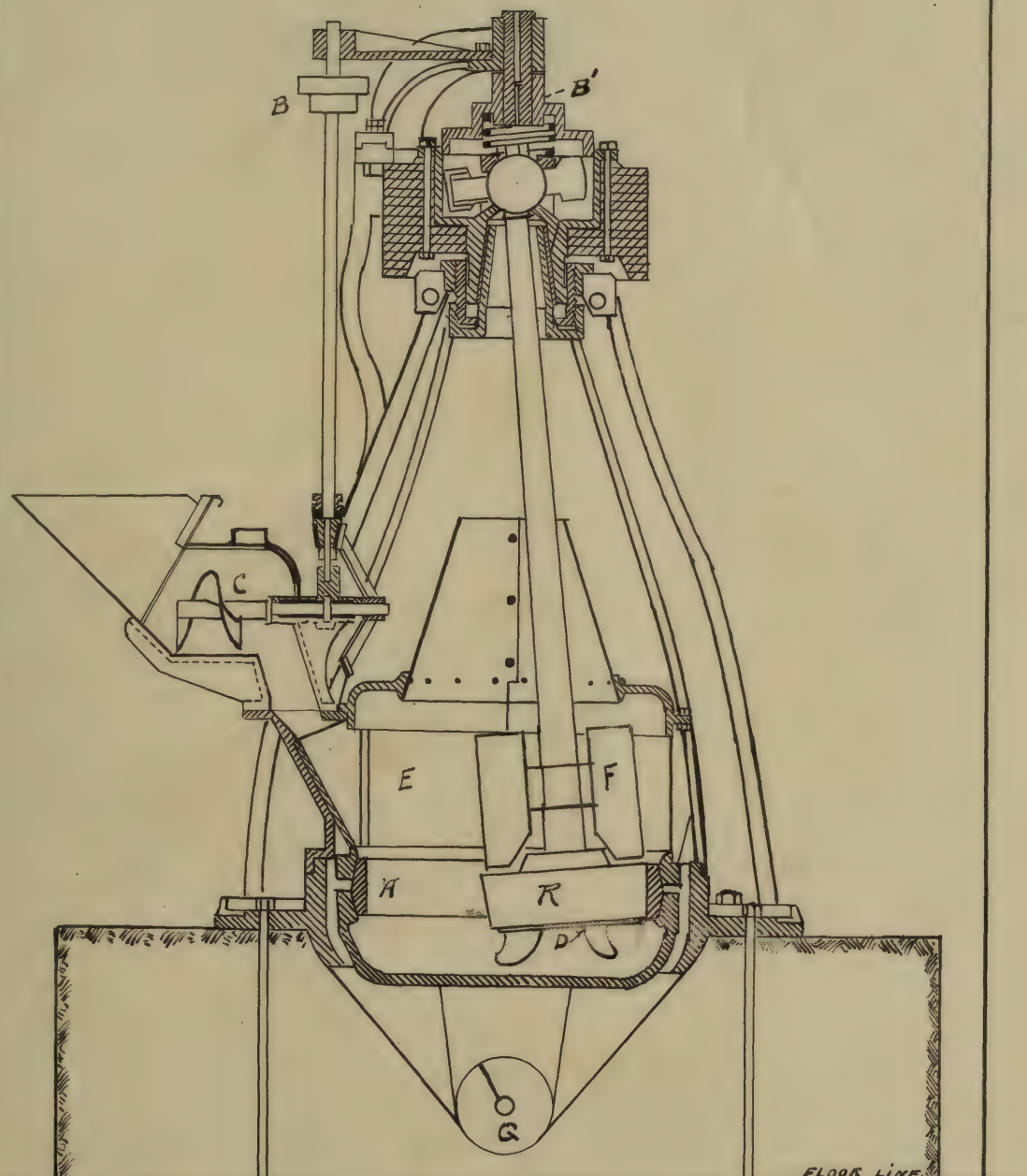
The pulverization of the soft coal was accomplished by means of the following mills.
2 Griffin Mills, 1 Trump Patent Ball Mill and 1 Trump Patent Ont Mill

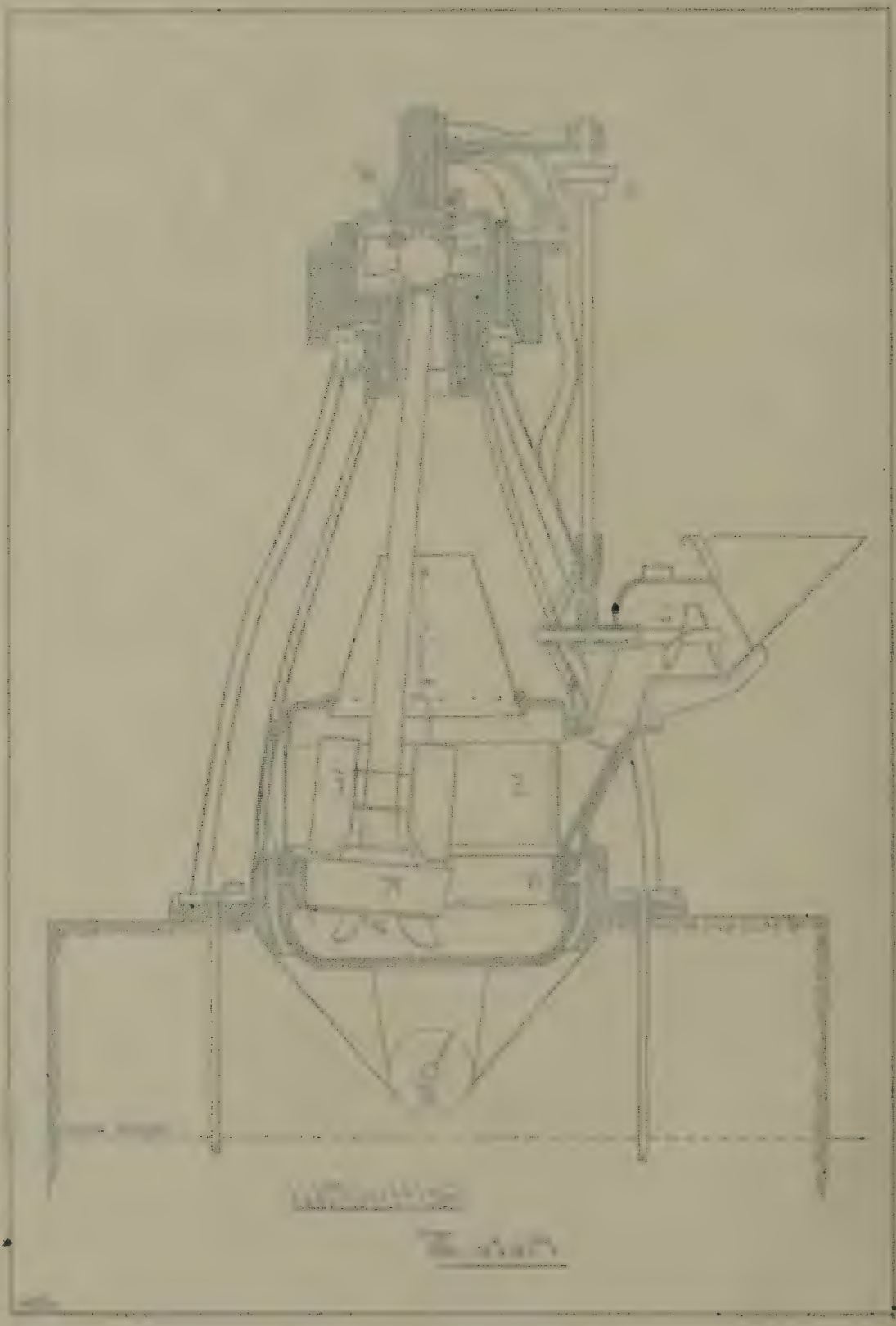
# The Griffin Mill.

The Griffin Mill is shown in Plate II
This mill is manufactured by the Bradley Pulverizer Co. of Boston Mass.
It is made in two sizes viz; 30 inch and 36 inch depending upon the inside diameter of the ring a die shown at A.
As will be seen from the drawing the mill consists of a central roll shaft suspended on trunions which fit into a recess in the bull wheel so that the shaft is compelled to revolve with the bull.
The shaft has two separate pendulum movements, one about the axis of the trunions and the other in a vertical plane through the axis of the trunions
A heavy spring which rests on the




Griffin Mill.

Plate II



Grinding balls tends to keep the shaft in a vertical position. By corresponding these movements the roll shaft can be moved so that the roll R will touch all points on the die A, without rotating the pulley.

When the pulley of the mill is rotated, the roll rolls around within the die ring, being thrown out against the die ring by centrifugal force. The material to be pulverized is fed into the hopper and finds its way into the mill by means of the screw conveyor C, the speed of which may be adjusted by the cone pulleys shown at B and B'. The material then falls into the base of the mill and is thrown up against the die in ring of the

moving shaft and roll with the follower plate attached
The follower plate is shown at D.
The roll coming in contact with the material pulverizes it, the dust produced in the pulverization is fanned out of the mill through the screen E by means of the steel fan F shrunk on the shaft directly over the roll.
Passing through the screen, the material drops down through the portholes into a conical shaped chamber beneath the mill, where it is conveyed away by means of a screw conveyor G.
The regulation of the amount of material fed to the mill is effected by means of the system of cone pulleys. The size of this particular

mill is known as the 30inch size.
The driving pulley is thirty inches
in diameter and is driven by a
ten inch double belt, the pulley
making 200 revolutions per
minute.
The screen used in this particular
mill is known as twenty two mesh,
number twenty two wire and is
made by the U.S. Tyler Co.
The mill is not dust proof it is
very noisy in its action and
costs considerable to keep in repair
breakages being quite frequent on
account of the jolting vibration
set up within the mill.
It is a common occurrence to break
as many as three roll shafts
within a month, nevertheless on
account of its ability to [illegible]

pulverize the most refractory substances with a small expenditure of power. It is extensively used by many of the largest eastern cement manufacturers.

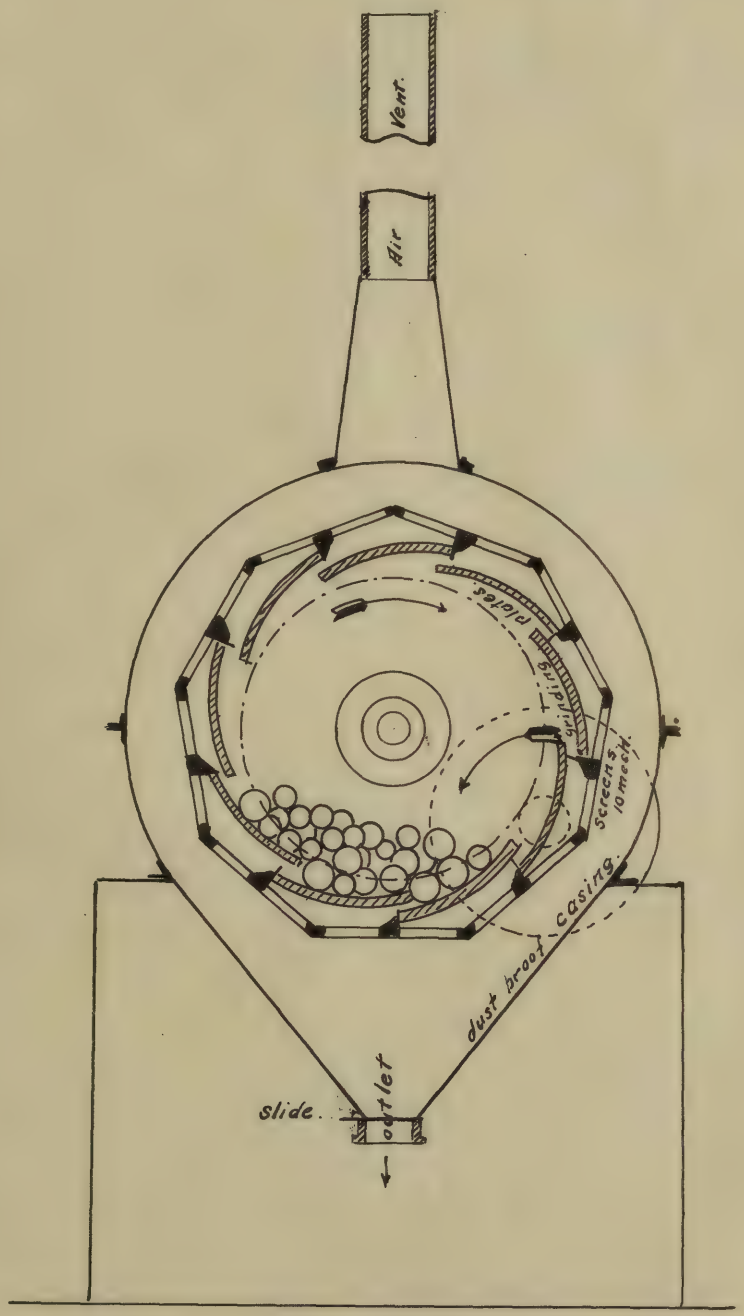
The Krupp Patent Ball Mill.

This mill consists essentially of a rotating drum about 8 feet inside diameter, the interior of which is composed of a series of grinding plates bent spirally and provided with holes through which the fine particles of the ground material fall.

The entire end walls of this mill are lined with chilled cast iron plates and are connected by wave discs to the steel shaft of the mill

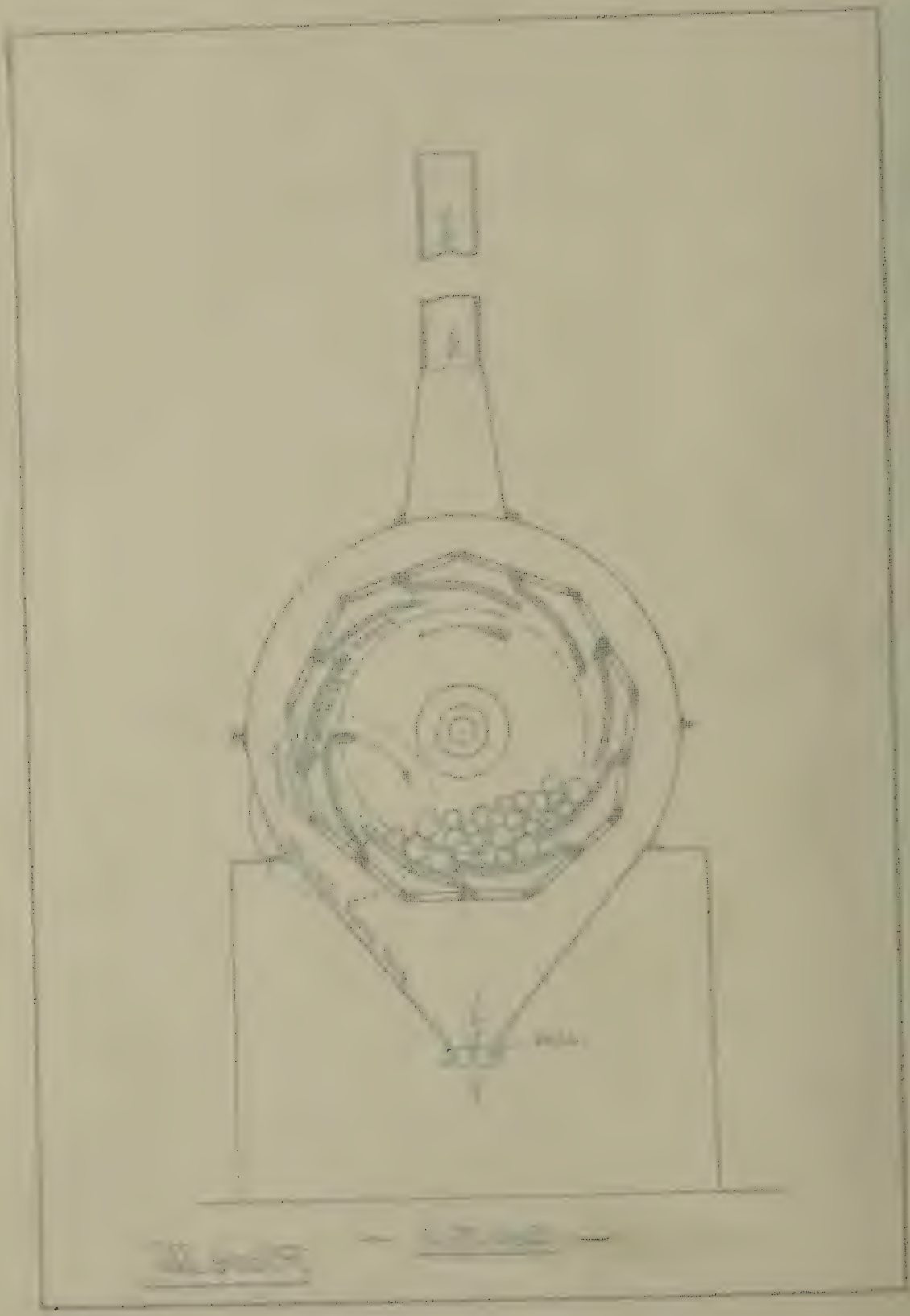
The Ball Mill is shown in Plate III

The material is fed into the mill




— Ball Mill. —

Plate III

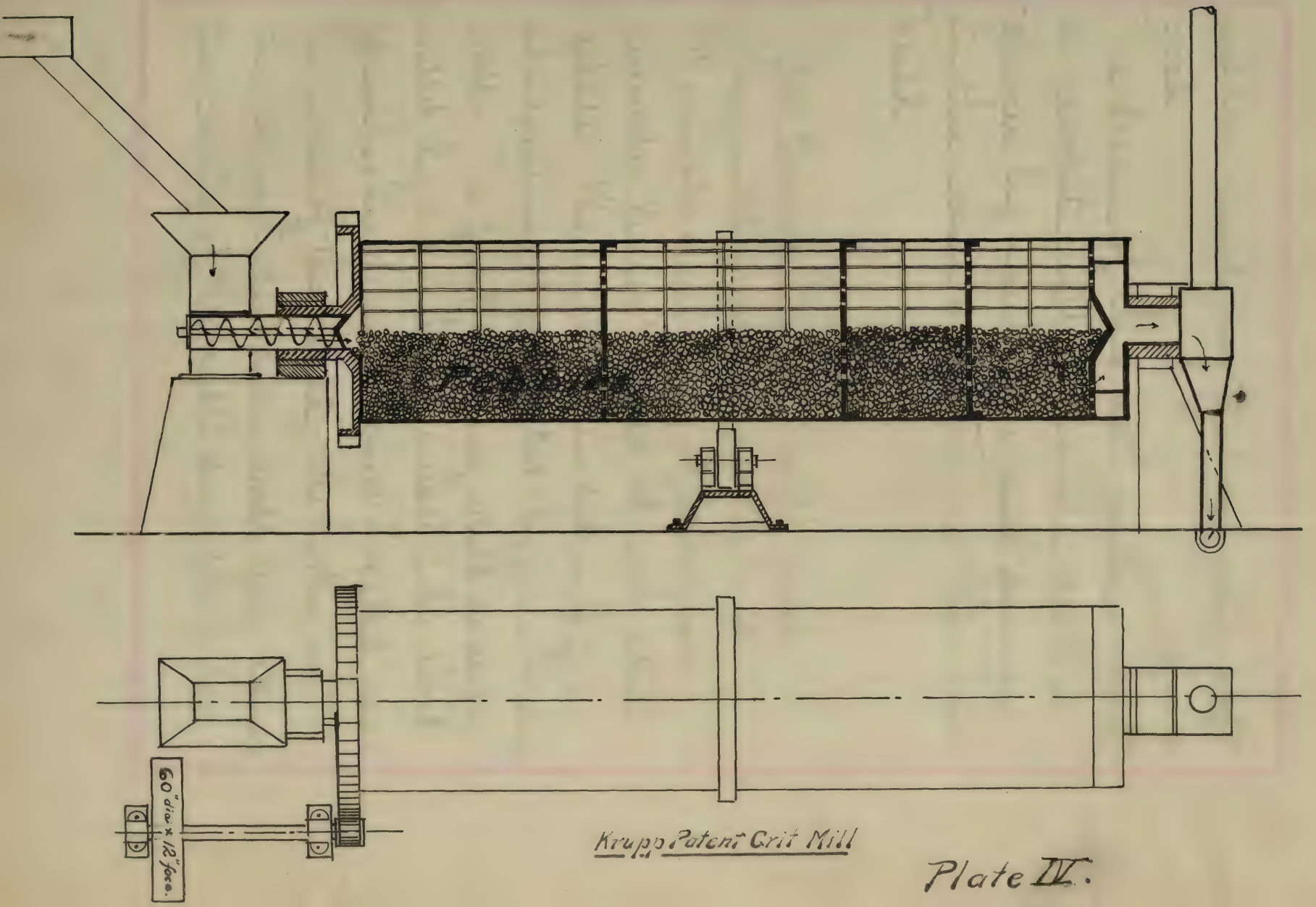


from the funnel shaped hopper by means of a shaft screw conveyor fixed to the shaft of the mill. In the interior of the mill are a great number of steel balls about 10 cm. in diameter. The rotation of the mill causes the balls to drop from one plate to another crushing the material in so doing. When the material has been sufficiently reduced it passes through the holes in the plates on to the co-axial screen (which consists of a series of screens having ten meshes to the linear inch.) The finished material finds its way through the screens, while the coarser particles fall back into the mill again to be further [illegible]

On account of the fineness of the coal generally fed to coal pulverizing mills, this mill is now very seldom used for coal grinding, the tube mill receiving the material direct. In this test the coal fed to the Ball Mill was so fine that the mill practically acted as a large screen and accomplished very little grinding. It was for this reason that the capacity and efficiency of this mill was not ascertained in making the tests as it is the intention to abandon this mill for the purpose of grinding coal.*

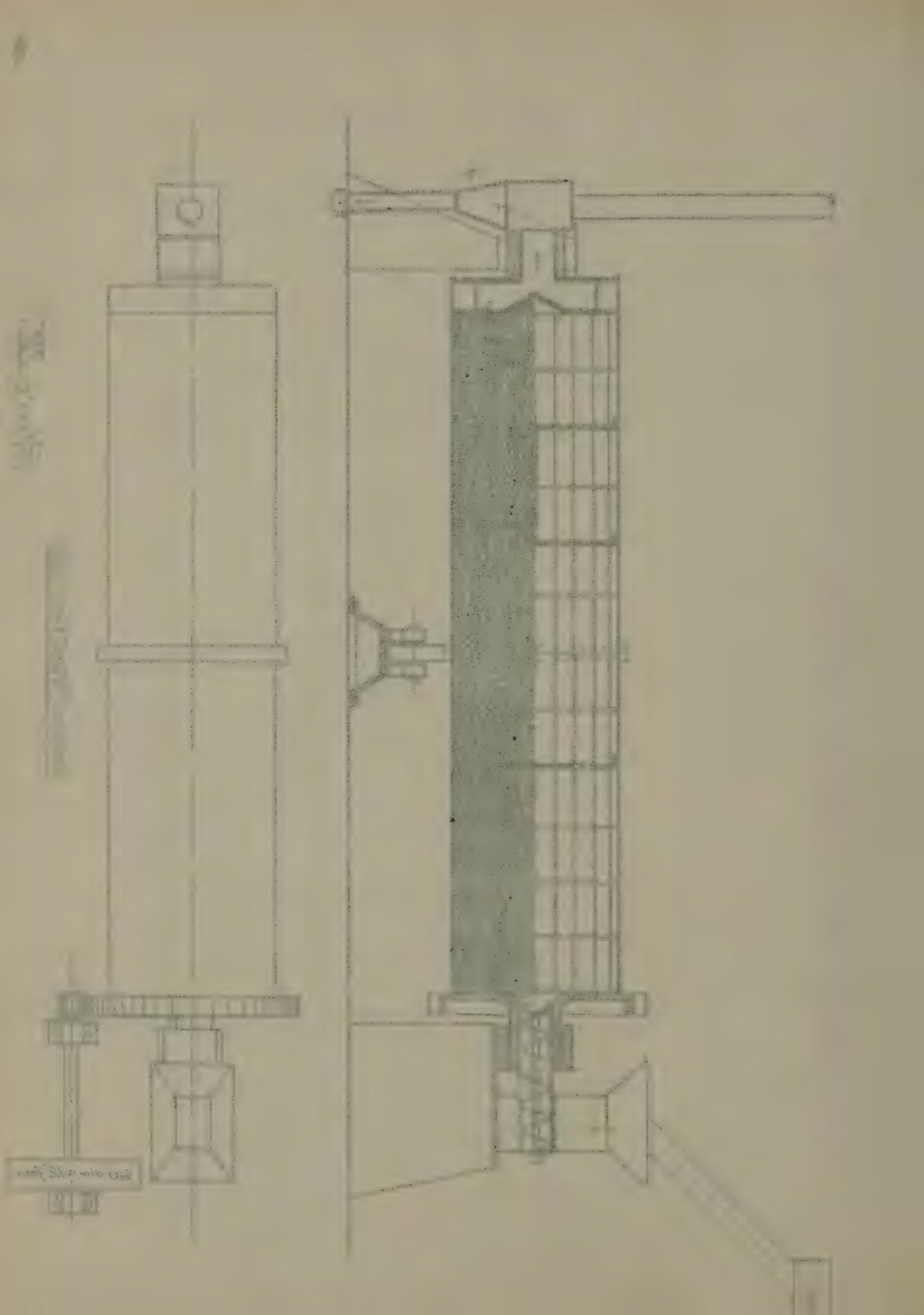
This mill is extensively used to pulverize cement clinker (a harsh and gritty material) but to accomplish it for the Tube & Ball Mill and to

* Later tests on Grit Mill made while feeding direct and not through Ball Mill show that the out-put of Grit Mill was not decreased, An out put of about four tons per hour being attained.




Krupp Patent Grit Mill

Plate IV.



seldom used in pulverizing soft coal.
The drum of this mill makes about 21 revolutions per minute and is driven by spur gear and pinion in the same manner as the tube mill.

The Kunz Patent Grit Mill.
This mill is shown in Plate IV
It consists essentially of a hollow cylinder lined throughout with steel plate. The mill is divided into four compartments separated by four dividing walls. The first dividing wall is perforated by a number of small holes about 1/4 inches in diameter and located near the shell of the mill, the holes in the second dividing wall are nearer the centre of the mill and the holes

in the end wall are placed near the circumference. By this means the material is compelled to travel through the entire mass of the pebbles, until it reaches the rear plate where it finds its outlet. The stack shown on the rear end of the mill acts as a vent.

The mill is driven by a large spur gear which meshes with a spur pinion. The mill revolves at a speed of 28 revolutions per minute.

The mill is supported on trunnions which fit into roller bearings. The bearings are also of the ball and socket type.

The material is fed into the mill by means of a screw conveyor about nine inches in diameter and fixed firmly to the mill and revolves with it. The

feed tube remaining stationary the material feeding through this tube.

The feed screw takes its supply from the feed hopper which is always kept full.

The feed to this mill is regulated by means of an overhead screw conveyor of the following dimensions 9 inch diameter, 9 inch pitch, flights 1/8 inch thick and built up on a solid steel shaft 2 7/16 inches in diameter. The mill took the maximum amount of coal when this screw conveyor made 12 revolutions per minute.

The method of driving the mill is by belting direct to the line shaft to the mill pulley which makes 172 revolutions per minute, this

ratio of the gearing being 96 to 14
A second tire forms a third bearing
to the mill which rests on idlers
& supporting rollers.
The third bearing is now abandoned
in mills of recent date.

## Test to determine the output of the Griffin Mill.

Duration of test, two hours and
twenty minutes.
Coal was fed continuously into
the hopper of the mill while mill
was in operation. The test began
with hopper full and ended with
hopper in same condition.
Two hundred bags of coal were
weighed out and set aside for the
test. The total weight of the coal
including the two hundred sacks

was found to be 11348 lbs.
Friends of coal fed to the mill -
All passed through screen having
two meshes to the linear inch and
ten per cent remained as residue on
1/4 inch mesh.
The height of the coal in the hopper
was maintained nearly constant
throughout the test. At the end
of two hours and twenty minutes
it was found that 186 sacks of coal
were used, leaving fourteen sacks
full.

| | |
|---|---|
| Weight of coal set aside for test | 11348 lbs |
| Weight of coal remaining (lbs) | 745 " |
| Weight of coal used including weight of sacks (lbs) | 10603 " |
| Weight of 186 empty sacks | 280 " |
| Net weight of coal ground | 10323 " |

The coal fed to the mill was [illegible]

de having passed through drier before being put in to crusher.
Gut-shut = 10323 lbs in 2⅓ hrs.
Gut-shut in pounds per hour = 4424
Gut-shut in tons of 2000 lbs
per hour = 2·212
Fairbanks standard platform scales were used throughout this test. The scales were tested by means of a standard 95 lb. weight and found to be correct.
Fineness of pulverized coal = 10% residue on 100 mesh.
Test of the Gut-shut & the Gut-mill
This mill was operated so that it was taking the maximum quantity of coal that could be passed through this mill without danger of clearing the feed screw, this was found to be the case when the overhead gud. conveyor made 12 revolutions per minute.

Results of the test were as follows

| | |
|---|---|
| Speed of Mill | 28 r. p. m. |
| Duration of test | 3 hrs. |
| Number of cars of coal ground | 615 |
| Total weight of 615 cars including weight of cars | 24625 lbs. |
| Dust collected from fan and not in cars | 83 " |
| Weight of 615 empty cars | 875 " |
| Net weight of coal ground | 23667 " |
| Net weight of coal ground per hour | 7889 " |
| Net weight of coal ground per hr. in tons of 2000 lbs | 3.944 Tons |

Fineness of finished coal - Ninety per cent passed sieve having one hundred meshes per linear inch.

The coal was collected and weighed as it passed from the discharge end of the mill

The same grade of coal was used in this test as was used in the Griffin Mill test. It contained no moisture as it was previously dried before passing through mill. The coal was fed to this mill as it came from the Ball Mill and was of the following fineness. All passed through screen having ten meshes to the linear inch, and all retained on screen having forty meshes to the linear inch, about seventy five per cent remained as residue on 22 mesh screen.

Power Test.

The mills were all driven direct from the line shaft by belting, any or all the mills could be thrown out of operation at will by means of friction clutch pulleys

The engine driving the mills was a Westinghouse standard having the following dimensions.

| | |
|---|---|
| Diameter of Cylinder | 20 inches |
| H.P. at 80 lbs steam pressure | 250 h.p. |
| H.P. at 90 .. .. .. | 281 .. .. |
| H.P. at 100 .. .. .. | 312 .. .. |
| Revolutions per minute | 250 |
| Piston speed (ft. per min.) | 666 |
| Diameter of pulley special | 42 in. |
| Width of belt (2 ply) | 24 in. |
| Size of Steam pipe | 8 .. |
| Size of Exhaust pipe | 10 .. |

Engine Constant

$$= \frac{2LA}{33000} = \frac{2 \times 16 \times 314.16}{33000} = .02538$$

and

$$h.p = .02538 \times (m.e.p.) \times (r.p.m.)$$

Indicator cards were taken at full load with all machines in operation. Table I gives the results of this test.

Table I

| Card No. | Area I | Area II | Mean Area. |
|---|---|---|---|
| 1 | 1.73 | 1.78 | 1.755 |
| 2 | 1.74 | 1.82 | 1.780 |
| 3 | 1.75 | 1.75 | 1.745 |
| 4 | 1.76 | 1.82 | 1.790 |
| 5 | 1.74 | 1.79 | 1.765 |
| 6 | 1.80 | 1.78 | 1.790 |
| 7 | 1.82 | 1.80 | 1.810 |
| 8 | 1.72 | 1.81 | 1.765 |
| 9 | 1.71 | 1.79 | 1.750 |
| 10 | 1.72 | 1.76 | 1.740 |

The mean area for the ten cards is then 1.769 sq. inches.

Length of diagram = $3\frac{1}{16}$ in. = 3.0625 in

Mean height of card = 0.5776 in.

Scale of spring = 60

M.E.P. = 0.5776 × 60 = 34.656

Revolutions of engine at full load as taken by speed indicator = 250 r.p.m.

Indicated h.p. = 250 × 34.656 × .6776
= 219.89

Indicator cards were next taken with all machinery running with the exception of two Griffin mills. The results are shown in Table II

| Card No. | Area I | Area II | Mean Area |
|---|---|---|---|
| 11 | 1.47 | 1.51 | 1.490 |
| 12 | 1.41 | 1.49 | 1.450 |
| 13 | 1.42 | 1.46 | 1.440 |
| 14 | 1.42 | 1.50 | 1.460 |
| 15 | 1.43 | 1.51 | 1.470 |
| 16 | 1.40 | 1.53 | 1.465 |
| 17 | 1.41 | 1.54 | 1.475 |
| 18 | .42 | 1.52 | 1.470 |
| 19 | 1.37 | 1.54 | 1.455 |
| 20 | 1.41 | 1.55 | 1.480 |

The mean area of the ten cards = 1.4655

Mean height = .4785

H. P. = .4785 × 60 = 28.71

Revolutions of engine = 255 r. p. m.

Variation of speed = $\frac{5 \times 100}{250}$ = 2 per cent

H. P. = 28.71 × 255 × .02538 = 185.79 H. P.

At an engine speed of 255 r. p. m. the speed of the mill is about two per cent greater than the normal speed.

The speed 250 is the speed under normal conditions, and the horse power developed by engine with this load and running 250 r. p. m would be

H. P. = 28.71 × 250 × .02538 = 182.16 H. P.

Subtracting 182.16 from 219.89 H. P. gives the net horse power absorbed in driving two Griffin mills. The net horse power absorbed in driving one Griffin mill would then be

$$\frac{219.89 - 182.16}{2} = 18.865 \text{ H. P.}$$

A third set of indicator cards were then taken with all machinery on with the exception of the Ball and Grit Mills. The results are shown in Table III

Table III

| Card No. | Area I | Area II | Mean Area. |
|---|---|---|---|
| 21 | 1.04 | 0.99 | 1.015 |
| 22 | 0.96 | 0.94 | 0.950 |
| 23 | 1.00 | 1.05 | 1.025 |
| 24 | .01 | 1.04 | 1.025 |
| 25 | 1.01 | 1.08 | 1.045 |
| 26 | 1.00 | 1.08 | 1.040 |
| 27 | 1.03 | 1.09 | 1.060 |
| 28 | 1.04 | 1.05 | 1.045 |
| 29 | 1.00 | 1.07 | 1.035 |
| 30 | 1.03 | 1.01 | 1.020 |

Mean area of the ten cards = 1.026

M.E.P. = (1.026 ÷ 3.0625) × 60 = 20.10

Revolutions per minute = 253 or 1.14 per cent variation from speed at full load.

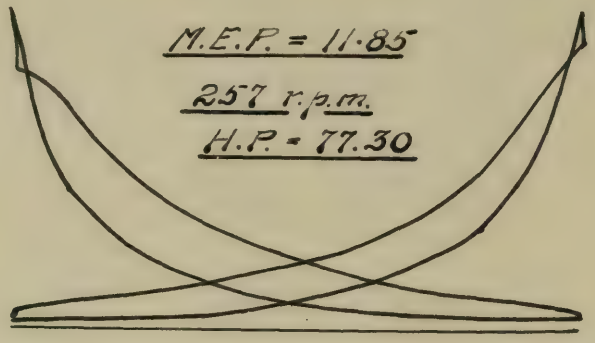
H.P. at 253 r.p.m. = 253 × 20.1 × .02538
= 129.08 ft. lb.

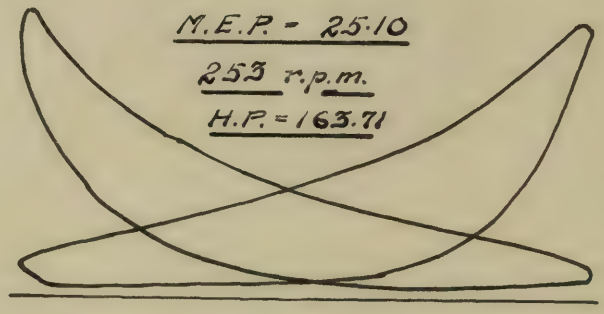
H.P. at 250 r.p.m. = 250 × 20.1 × .02538
= 127.63 ft. lb.

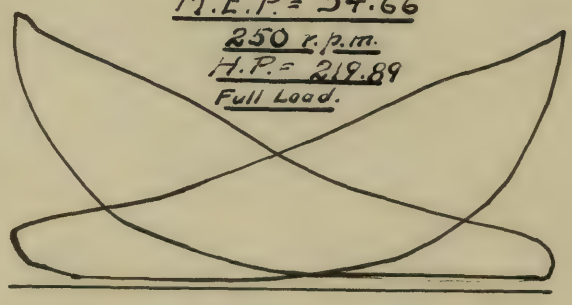
Pure power required to drive the Ball and Grit Mills = 219.89 − 127.63
= 92.26 ft. lb.

A fourth set of indicator cards was next taken with full load on less the two Griffin Mills and the Ball Mill. The results are given in Table IV

| Card No | Area I | Area II | Mean Area. |
|---|---|---|---|
| 31 | 1.38 | 1.29 | 1.335 |
| 32 | 1.32 | 1.36 | 1.340 |
| 33 | 1.26 | 1.32 | 1.290 |
| 34 | 1.21 | 1.29 | 1.250 |
| 35 | 1.26 | 1.32 | 1.290 |
| 36 | 1.32 | 1.37 | 1.345 |
| 37 | 1.26 | 1.32 | 1.290 |
| 38 | 1.20 | 1.25 | 1.225 |
| 39 | 1.20 | 1.22 | 1.210 |
| 40 | 1.20 | 1.28 | 1.240 |




Westinghouse Std. Engine #4356 - 20" × 16"

Scale of Spring = 80.

Plate V.

FHN.

The mean area of the above cards = 1.2815"
M. E. P. = (1.2815" ÷ 3.0625") × 60 = 25.104
Revolutions per minute = 253
H.P. developed at this speed = 161.20
H.P. developed at 250 r.p.m = 159.28
Subtracting this from 219.89 gives 60.61 ft. lbs required to drive the two Griffin Mills and one Ball Mill. But 37.73 ft. lbs. is required to drive the two Griffin Mills Then 60.61 - 37.73 = 22.88 ft. lbs. is required to drive the Ball Mill. Subtracting this from 92.36 the brake power required to drive the Ball and Grit Mill gives

92.36 - 22.88 = 69.48 ft. lbs.

required to drive Grit Mill.

Tracings of a few of the indicator cards taken during test is shown by Plate V.

## Summary

Net horse power required to drive
one Griffin Mill 18.91 h.p.
Net out-put of Griffin Mill
of pulverized coal in pounds
per hour. 4424 lbs
Ditto. in tons of 2000 lbs 2.212
Net horse power required to
drive Grit Mill = 69.24 h.p.
Net out-put of Grit Mill
of pulverized coal in lbs
per hour. = 7889 lbs.
Ditto in tons of 2000 lbs = 3.9445
Pounds of coal per horse
power hour, pulverized by
Griffin Mill. = 233.95 lbs
Pounds of coal per horse
power hour pulverized by
Grit Mill = 113.77 lbs
Difference in favor of
Griffin Mill = 120.18 lbs

The Griffin mill will then save over 10.5 per cent more coal per horse power hour than the Grist mill.
A comparison of the cost to grind one ton (2000 lbs) of coal by each mill.
In what is to follow the following assumptions have been made.
Pounds of pea coal consumed under boilers per indicated horse power hour = .3 lbs.
Cost of pea coal per ton of 2000 lbs = $2.20
The average cost per Griffin mill for repairs parts for 24 hrs run = $2.08
Total Coal burned under boilers per day for Griffin Mill = 18.91 × 3 × 24
= 1361.5 lbs.
Cost of same = $1.50
Cost for power and repairs for one days run (not including wages)
= $3.58

Cut. Out of Griffin Mill in tons per day = 53.07

Cost to pulverize one ton of soft coal (wages excluded) = $.0674

Tube Mill

Coal burned for power per 24 hrs =

$$\frac{69.34 \times 3 \times 24}{2000} = 2.496 \text{ tons}$$

Cost for same $5.49

Cost of repairs per day .55

Cut. Out of Tube Mill in tons per day = 94.656

Cost per ton (wages excluded) $.0638

The cost then of grinding coal by the tube system is practically the same provided the cost of labor is not figured.

The breakages on a Griffin Mill occur quite frequently, the repair costs are expensive, and the mill

requires constant attention, the cost of labor being greatly in excess of that required to operate the Griffin mill.

The Griffin mill requires little attention, breakages seldom occur and very little time is lost in making repairs.

At the rate of two dollars per day for repair parts to the Griffin mill the cost for one year would amount to seven hundred and twenty dollars. The cost of the Griffin mill including foundations is approximately two thousand five hundred dollars. At the above rate an installation of Griffin mills would completely destroy itself in three and one half years.

The cost of a Grist mill including

foundations is approximately $3200.00, at the rate of two hundred dollars per year for repairs, the total cost $3200 would be expended in sixteen years. The only ~~cost~~ repairs to a Grit Mill is renewing the pebbles, gears and steel lining. In a Griffin Mill there is scarcely a part which does not require to be renewed during the year. The fan shieves, whose sole purpose it is to fan the material through the sieves are often taken out of the mill entirely stripped of the fan blades. The mill shafts four and one quarter inches in diameter sometimes snap like a piece of chalk. The mill is constructed of the finest materials procurable, nevertheless the breakages are quite frequent. This can only

be ascribed to the excessive vibration set up in operating the mill

S. Perry Bannister

March 4th 1901

In preparing this paper, permission has been granted by Messrs. J. E. Lober and Wm. R. Dunn, vice president and superintendent respectively of the Vulcanite Portland Cement Co. to use data of tests conducted by me.

S. Perry Bannister

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